Study the Relationship Between Teacher Literacy and Student Learning Outcomes in Math

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Abstract

The rapid development of science and technology significantly improved the quality and efficiency of education. This paper aimed to study mathematics, the most important subject in high school education, and explored how teachers' technological literacy, curriculum design, attitudes towards technology, and professional development for technology integration affected the student learning outcomes in the form of a questionnaire about 214 teachers who participated. The objective consistency index (IOC) was used to evaluate the content validity of the project during the research phase. The results showed that, except for one item, all other items exhibited good consistency. From most to least significant, the factors influencing student learning outcomes are teachers' technical literacy > curriculum design > attitude toward technology > development of mathematics education for teachers, with correlation coefficients of 0.608, 0.447, 0.436, and 0.289, respectively. Teacher technological literacy, curriculum design, and attitude toward technology were significantly positively correlated with student learning outcomes and could promote learning effectiveness. Technology was developing rapidly. Teachers' technical literacy, curriculum design, and attitude towards technology were all actively changed with the times, effectively stimulating students' interest in learning from multiple dimensions and thus improving students' confidence in learning.

Keywords ： *Teacher Technology Literacy, Curriculum Design, Attitude towards Technology, Learning Outcome*

1 Introduction

In recent years, technological integration has changed the landscape of teaching. This progress was most apparent in cities such as Shanghai, where cutting-edge technology and forward-thinking policy have converged to create an environment ripe for new approaches. The study was located in the core-first metropolis of Shanghai, a site of rapid modernization and technological penetration (1).

Over time, technology in education gradually shifted from merely a helpful aid to the whole kit and caboodle of a complete curriculum. A critical factor in this transition was the role of teachers. Their competence in using technological tools and their orientations towards

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technology largely determined how well technology was integrated into the classroom. This study aimed to examine the intricate dynamics associated with learning outcomes and teacher technological literacy, exploring how teachers' capacity and perceptions influence student academic experiences. A well-designed curriculum incorporating technology like this creates an interactive and engaging learning environment that is perfect for students to hone their critical thinking skills and problem-solving (2). The attitude of teachers towards technology was another important factor in ensuring the successful adaptation and rise of digital tools in education. An understanding of the influence that experienced, such as teachers' level of comfort with technology, perceived value for integrating it into their classroom practice, and acknowledgment obtained from the institution plays in shaping teacher's attitudes towards teaching technologies was important to cultivating a positive technological culture within k-12 schools (3).

Teachers' continuous professional development programs could work to increase teacher technological literacy and pedagogical skills that would, in turn, improve teachers' efficacy over technology integration (4). The high educational standards in Shanghai required training resources for teachers to get the most out of a digital environment. This report investigated the consequences of these types of professional development on teachers' use and regarding technology in classroom practices, thus, pupil knowledge (5). Ensuring policymakers and educational institutes are key in bridging the gaps will lead to an inclusive experience that maximizes technology (6).

This study underscored the importance of early prevention through targeted intervention at a key moment in 3rd-grade math education and revealed long-term benefits attributable to technology-enhanced learning. Educational technology could make great strides in revolutionizing instructional practices. However, its efficacy depends on the technological literacy of teachers, pedagogic-designed content with educational technologies, and all-inclusive teacher support (7).

Technology integration in primary education, particularly in mathematics instruction, had become increasingly prevalent in Shanghai's 3rd-grade classrooms. Interactive whiteboards have revolutionized the way geometric concepts are presented, allowing teachers to dynamically illustrate shapes, angles, and spatial relationships (8).

Virtual manipulatives have emerged as a powerful resource for teaching fractions, a concept many young learners find challenging. These digital tools enabled students to interact with representations of fractions in ways that physical manipulatives cannot, fostering a deeper understanding of part-whole relationships and equivalence (9). Furthermore, game-based learning platforms have transformed traditional problem-solving exercises into engaging, interactive experiences. By incorporating game design elements such as points, headboards, and narrative contexts, these platforms motivated students to persist in solving mathematical problems and develop critical thinking skills (10). Dynamic

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visualization could help students develop a deeper understanding of geometric concepts at an early age (11). Additionally, game-based learning platforms have shown promise in increasing student motivation and engagement in mathematics, particularly for primary school children (12).

However, it is important to note that the effectiveness of technology in primary mathematics education depends significantly on how it is implemented. The role of the teacher in selecting appropriate digital tools, integrating them meaningfully into instruction, and guiding students in their use was crucial (13). In this study, we attempted to consider the different aspects of these challenges, focusing on third-grade mathematics education within urban Shanghai (14). This research would ultimately offer a deeper insight into the links between teacher technological literacy, curriculum design, attitudes, and professional development to understand better what enables or hinders successful technology integration(11). Therefore, This research seeks to offer practical guidelines for urban schools to optimize learning opportunities by identifying key factors that influence technology integration efficacy, enhancing student achievement (15).

2 Research Methode

In this study, we took third-grade mathematics as an example to examine whether there was a significant positive correlation between teacher technology literacy and student learning efficiency with a quantitative research design through a questionnaire. The quantitative approach may offer a structured and systematic method of measuring numerical data, which could be necessary for identifying or verifying specific patterns between variables. Specific objectives were to examine the state of technological literacy among teachers, the effects of technology-rich curriculum design in schools and teaching briefs, attitudes towards technologies held by teachers for students, and important policy school-based intervention strategies. This research employed a quantitative design to produce objective, generalized results that can be communicated to educational policy and practice.

The quantitative research design employed in this study offered several key advantages that make it particularly suitable for examining the relationship between teacher technological literacy and student learning outcomes in third-grade mathematics in urban Shanghai schools. Primarily, this approach allowed for the collection and analysis of numerical data, enabling the identification and verification of specific patterns and relationships between variables. This was crucial for establishing a clear, evidence-based understanding of how teachers' technological literacy impacted student learning efficiency.

Quantitative research's structured and systematic nature provided a robust framework for measuring complex constructs such as technological literacy, curriculum design effectiveness, and learning outcomes. Using standardized instruments and statistical analyses, the study could produce objective, replicated results that are less susceptible to researcher bias. Furthermore, the quantitative approach facilitates the generalization of

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findings to a broader population, which was particularly valuable in urban Shanghai's educational landscape. Using appropriate sampling techniques and statistical methods, the study could draw conclusions that may be applicable beyond the immediate sample, providing insights relevant to other urban educational settings. The research framework is shown in the figure below.

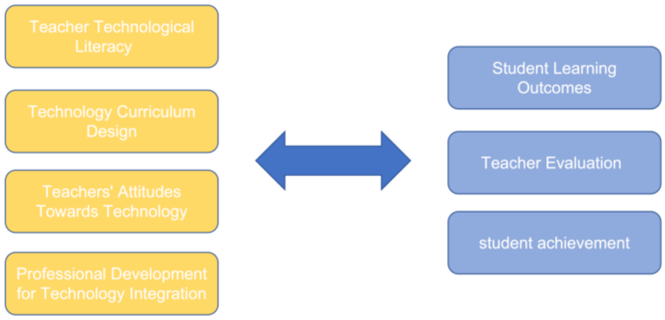

Figure 1: Conceptual Framework

Krejcie and Morgan's (1970) table was used to determine the sample size for this study. According to the table, for a population of 550 teachers, a sample size of 226 was required to ensure a 95% confidence level and a margin of error of ±5%. Therefore, the study would include 226 teachers. This sample size was sufficient to provide reliable and valid results that could be generalized to the larger population.

3. Results

3.1Pilot Study

Before the primary research, a pilot study would be conducted to test and refine the research instruments, procedures, and overall study design. This crucial step would help identify potential issues and improve the validity and reliability of the full-scale study. The pilot study would involve a small sample of 30 third-grade mathematics teachers from urban schools in Shanghai, selected using the same criteria as the main study but excluded from the final sample.

The pilot study will begin by administering the teacher technological literacy questionnaire to the selected teachers. This would allow us to assess the clarity of the questions, the time required to complete the survey, and the effectiveness of the online survey platform. Teachers would be encouraged to provide feedback on any ambiguous or confusing items, which would be used to refine the questionnaire.

Following the administration of the teacher questionnaires, we would conduct preliminary data analysis to evaluate the psychometric properties of the instruments. This would include calculating internal consistency reliability (Cronbach's alpha) for the teacher technological literacy scale and item analysis for the teacher questionnaire. Factor analysis would be performed on the teacher questionnaire to confirm its underlying structure and construct validity. A reliability analysis of questionnaire items was made in the pilot study.

Table 1: Reliability analysis of questionnaire items

Reliability Statistics	Cronbach's Alpha	N of Items
Teacher Technology Literacy	0.933	7
Curriculum Design	0.733	7
Attitude towards Technology	0.899	6
Professional Development	0.919	4
Learning Outcome	0.955	5

The Cronbach's alpha value of 0.933 for the teacher technology literacy scale indicated excellent internal consistency reliability. This high value suggested that the 7 items in this scale were strongly interrelated and consistently measured the same underlying construct of teacher technological literacy. It implied that teachers' responses to these items are highly consistent across the scale, providing a reliable measure of their technological competence. This strong reliability gave us confidence in the scale's ability to assess teachers' technological literacy levels accurately.

The curriculum design, attitude towards technology, professional development, and learning outcome scale showed a Cronbach's Alpha of 0.733,0.899,0.919, 0.955, indicating good internal consistency reliability. These values were above the commonly accepted threshold of 0.7 for acceptable reliability. This scale's items appeared to measure related aspects of curriculum design with reasonable consistency. This suggested that the scale provided a reliable measure of teachers' approaches to curriculum design, attitude towards technology, professional development, and learning outcomes. However, there might be some variability in how teachers interpret or respond to certain items within the scale. This high reliability allowed for great confidence in the scale's ability to assess accurately and represent the items in the context of this study.

The promising reliability results from the pilot study justified proceeding with the full research for several reasons. These results indicated that the research instruments were well-prepared to yield reliable and meaningful data in the full-scale investigation of the relationship between teacher technological literacy and student learning outcomes in mathematics.

3.2Descriptive statistical analysis of the sample

Applying technology in education was much more complex and involved various factors, including curriculum design, teacher training, and ensuring institutional support. The careful design of a technology-rich curriculum was essential to support the effective use of digital tools in learning.

In order to make a specific analysis of the research object, 226 questionnaires were distributed, but 214 valid questionnaires were collected in this paper. The frequency and percentage were statistically analyzed, and the basic information of the sample is shown in the table below:

Table 2 The basic information of the sample

Project	Option	Frequency	Percentage
sex	male	147	68.70%
	female	67	31.30%
age	20-29years	39	18.30%
	30-39 years	85	39.50%
	40-49 years	64	30.10%
	50-59 years	24	11.40%
	≥60 years	1	0.70%
record of formal schooling	baccalaureate	137	64.10%
	Master	66	31.00%
	doctor	8	3.90%
	other	2	1.00%
Teaching experience	0-5years	22	10.10%
	6-10 years	36	17.00%
	11-15 years	64	30.10%
	16-20 years	68	31.70%
	≥20 years	24	11.10%
Access to educational technology training	No formal training	15	6.90%
	Short courses or seminars	99	46.10%
	Certificate courses	90	41.80%
	Bachelor of Education in Technology	4	2.00%
	other	7	3.30%

From the above table, it was known that the gender distribution of the survey subjects showed a significantly higher proportion of male employees compared to female employees, with male employees accounting for 68.7% and female employees accounting for 31.3% among all employees. High school mathematics was often considered the most important subject in high school, and due to personal family influences, women were often perceived as having less energy than men. Moreover, mathematics was believed to test logical thinking abilities, which were generally considered stronger in males than females.

Mathematics was the most important subject in high school education, so most math teachers were also class teachers, and they were often considered rich in teaching experience. Among them, the proportion of middle-aged and elderly employees over 30 years old was 81.7% (among which, the proportion of 30-39 years old was 39.5%, the proportion of 40-49 years old was 30.1%, and the proportion of employees over 50 years old was 11.4%).

The sample employees' teaching experiences were mainly 11-15 years and 16-20 years (30.1% and 31.7%, respectively). Most sample employees had obtained a master's degree (64.1%). In comparison, the proportion of master's degree holders in Shanghai was 3.77%, indicating that the educational level of high school teachers was generally high.

Regarding professional development and support for technology integration, most were acquired in the form of short courses or seminars, and only 6 people were provided with professional development and support for technology integration, indicating that professional technical personnel are needed to provide technology support.

3.3The Study Of Objective Consistency Study Of Indicators

The Objective Consistency Index (IOC) was introduced by Rovinelli and Hambleton in 1977. IOC was used for testing development to evaluate the content validity at various stages of project development. The evaluation process using IOC involved evaluators scoring each project based on their ability to measure the extent to which test developers meet specific objectives listed by the project. Experts assessed each project by assigning scores of +1(clear measurement), 0(measurement uncertainty), and -1(not sure).

The experts involved in the study were not informed in advance about the structure of the individual items to be measured and, therefore, remained independent and impartial assessors.

The table below shows IOC on learning outcomes, teacher technology literacy, curriculum design, attitude toward technology, and professional development.

Table 3: IOC on learning outcome

IOC on learning outcome	Exp 1	Exp 2	Exp 3	IOC index
The academic quality of this online class is on par with the face-to-face classes I have taken.	1	1	1	1
I have learned as much from this online class as I might have from the face-to-face version of the course.	1	1	1	1
I learn more in online classes than in face-to-face classes.	1	1	1	1
The quality of the learning experience in online classes is better than in face-to-face classes.	1	1	1	1

Table 4: IOC on teacher technology literacy

IOC on teacher technology literacy	Exp 1	Exp 2	Exp3	IOC index
I am good at running a computer and software.	1	1	1	1
I can carry out computer maintenance.	1	1	1	1
I can use the basic features that are common in most software.	0	1	1	0.67
I can use the advanced features easily, which are common in most software.	1	1	1	1
I am good at using word processors, spreadsheets, databases, presentation programs, web design programs, and communication programs.	1	1	1	1
I am good at using the basic features of word processors.	1	1	1	1
I am good at using programming languages and developing software.	1	0	1	0.67

Table 5: IOC on curriculum design

IOC on curriculum design	Exp 1	Exp 2	Exp3	IOC index
I consider the characteristics of the students I will teach.	1	1	1	1
I consider how the course is related to the other courses.	1	1	1	1
I write down the general/specific goals of the course.	0	1	1	0.67

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IOC on curriculum design	Exp 1	Exp 2	Exp3	IOC index
I determine the course learning tasks/activities.	1	1	1	1
I prepare the course readings.	1	0	1	0.67
I regularly engage in seasonal activities (e.g., snow shoveling or heavy gardening).	1	1	1	1
I check my course plan with the Head of the department or colleagues.	1	1	1	1

Table 6: IOC on attitude towards technology

IOC on attitude towards technology	Exp1	Exp2	Exp3	IOC index
I enjoy using technology for personal/recreational matters.	1	1	1	1
I am confident using technology for personal/recreational matters.	0	0	1	0.33
I have a positive attitude towards technology for recreational matters.	1	1	1	1
I enjoy using technology for learning.	1	1	1	1
I am confident in using technology for learning.	1	1	1	1
I have a positive attitude towards technology for learning.	1	0	1	0.67

Table 7: IOC on professional development

IOC on professional development	Exp1	Exp2	Exp3	IOC index
All tutors are engaged in professional learning.	1	1	1	1
Professional development is linked to the individual as well as KPT priorities.	1	1	1	1
Professional learning is evaluated effectively at both the individual and KPT levels.	1	1	1	1
Professional development will be sustained and improved in the future.	1	1	1	1

As seen from the table above, except for one item, the IOC on attitude towards technology, 'I am confident using technology for personal/recreational' matters, was 0.33. All the rest of the items showed good consistency.

3.4 Correlation study of various factors

This study was divided into 4 groups, and the correlation of each factor was studied by Pearson correlation. The results are shown in the following table:

Table 8： 4 Group of correlation studies

Groups	Pearson correlation/P-value			
Groups	Technology Literacy	Curriculum design	attitude towards technology	professional development
1	0.616/＜0.001	0.51/＜0.001	0.538/＜0.001	0.167/＜0.218
2	0.808/＜0.001	0.538/＜0.001	0.553/＜0.001	0.405/＜0.010
3	0.457/＜0.001	0.293/＜0.05	0.206/＜0.114	0.236/＜0.070
4	0.549/＜0.001	0.446/＜0.001	0.446/＜0.001	0.347/＜0.010
average	0.608	0.447	0.436	0.289

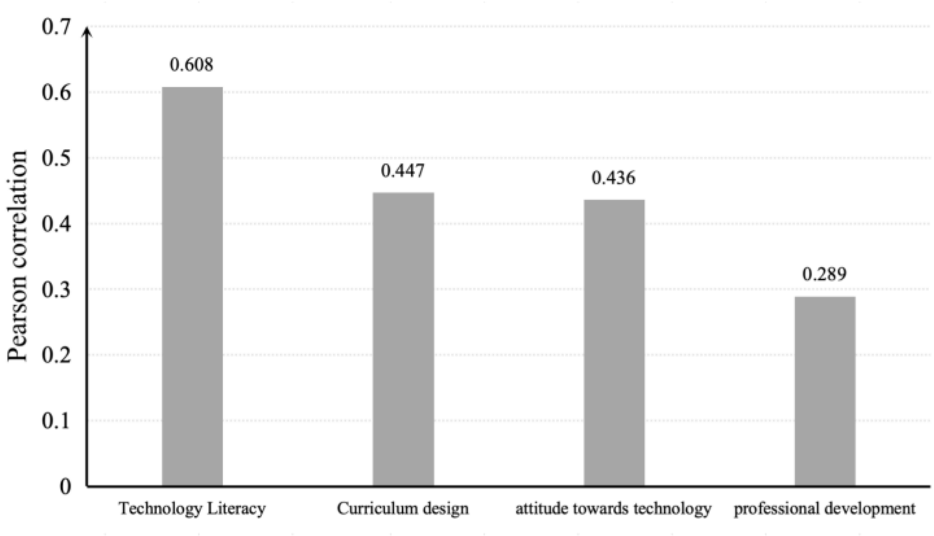

Figure 2: Pearson correlation analysis

This study used Pearson correlation analysis to explore the interrelation between multiple dimensions of teachers' mathematics teaching about technology and students' learning outcomes. The analysis showed that:

There was a significant positive correlation between teachers' technical literacy in mathematics teaching and students' learning outcomes, with an average correlation coefficient of 0.608 ($p<0.001$) and a sample size of 214, indicating that the higher the level of technical literacy teachers possessed in mathematics teaching, the better the students learning outcomes tended to be, and this correlation was statistically highly significant.

The average correlation coefficient between the teacher's design of the mathematics curriculum and the students' learning outcome was 0.447, reflecting that the teacher's careful design of the mathematics curriculum can effectively promote improving students' learning outcomes.

In addition, the average correlation coefficient between teachers' attitudes toward the use of technology in mathematics teaching and students' learning outcomes was also 0.436 ($p<0.001$). It revealed that teachers actively use technology in teaching, which had a significant positive promoting effect on students' learning outcomes.

The correlation coefficient between the professional development of mathematics teacher education and student learning outcomes was 0.289, indicating that the improvement of teachers' level of mathematics education positively impacted student learning outcomes.

Teachers' literacy in mathematics teaching played the most important role, being highly consistent with their attitudes towards curriculum design and closely linked to professional development, thereby significantly impacting students' mathematics learning outcomes.

In comparison, from most to least significant, the factors affecting students' learning outcomes were teachers' technical literacy > course design > attitude towards technology> professional development for technology integration. It was evident that under the current technological advancements, methods such as online resources, virtual reality education, and big data analysis were increasingly being integrated into teaching. How to effectively utilize these digital tools placed high demands on teachers' technical literacy. Therefore, whether teachers possess excellent technical skills has a significant positive impact on students' learning outcomes. The relationship between course design and teachers' attitudes towards technology differed significantly between learning outcomes. With the rapid development of technology, teachers should adopt a proactive learning attitude and incorporate more new technologies into their course designs, which hold great significance in capturing students' attention and stimulating their interest in learning. Among the four influencing factors, although professional development for technology integration was the lowest, there was still a positive linear correlation between them, indicating that traditional mathematics education needs to be actively improved to keep up with the times and introduce new technologies.

4. Conclusion

Technological advancements have significantly enhanced the quality and efficiency of education. This study focused on mathematics, the most important subject in high school education, exploring teachers' technological literacy, curriculum design, attitudes towards

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the use of technology in mathematics instruction, professional development for technology integration, and the relationship between these 4 factors above and student learning outcomes.

The pilot study was conducted to test and refine the research instruments, procedures, and overall study design. The consistency coefficient between teacher technological literacy, technology curriculum design, teachers' attitudes towards technology, professional development for technology integration, and student learning outcomes was relatively high, and it showed that student learning outcomes could be seen in these four factors.

The potential structure and structural validity were determined using Cronbach's Alpha by analyzing questionnaire surveys by teachers and students. The Cronbach's Alpha of the teacher technical literacy, technology curriculum design, teachers' attitude towards technology, professional development for technology integration, and student learning outcomes were 0.933, 0.733, 0.899, 0.919, 0.955. All these values indicated that the project has good internal consistency and reliability.

Regarding consistency in survey results, objective consistency was used to evaluate the content validity during the project research phase. The results showed that, except for one item, which IOC on attitude towards technology, 'I am confident using technology for personal/recreational matters', was 0.33, and all other items exhibited good consistency. This fully demonstrated the significance and data validity of this study.

The 4 factors played an active role in promoting teaching outcomes. Teacher technological literacy was significantly positively correlated with student learning outcomes and could promote learning effectiveness. Among the four factors, this one had the highest average value. It was evident that enhancing teachers' technological literacy could optimize the teaching process, improve teaching efficiency, and improve students' academic performance.

The average correlation coefficient between teachers' attitudes toward technology, curriculum design, and students' learning results was 0.446 and 0.436. It reflected that teachers' carefully designed mathematics curriculum could effectively promote the improvement of students' learning results. There was also a significant positive correlation between the mathematics curriculum design and students' learning outcomes.

The correlation coefficient between professional development for technology integration and student learning outcomes was 0.289, the lowest among the four items. This may indicate that teachers' professional educational background had a relatively limited impact on student learning outcomes or that other mediating or moderating variables were at play.

The technical competence of teachers was the key soft power in educational digitization, directly impacting the direction and effectiveness of this transformation. In the digital age, mathematics education must continuously integrate new digital technology elements, reexamining and reconstructing the modernity of mathematical literacy through digital competence.

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